Application for
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of

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for

THE METHOD OF SERVO WRITING FOR MAGNETIC RECORDING SYSTEM, MAGNETIC RECORDING SYSTEM

THE METHOD OF SERVO WRITING FOR MAGNETIC RECORDING

SYSTEM, MAGNETIC RECORDING SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a magnetic recording system comprising perpendicular magnetic

5   recording media.

Description of the Related Art

The magnetic recording system is such that the head is moved radially of a rotating disk and accurately set in position on an intended data track to

10 write and read information magnetically. A top plane view of the interior of a housing (enclosure) of a typical magnetic recording system is shown in Fig. 10, and a sectional view of the magnetic recording system is shown in Fig. 11. These diagrams illustrate a

15 magnetic recording system configured of six heads, three disks, a rotary actuator, a voice coil motor, a head amplifier and a package board.

The three disks are fixed on a single rotary shaft and driven at the rotation speed of 3000 to 15000

20 rpm around a point A by a spindle motor. The six heads are fixed on a single comb-shaped arm and rotationally driven around a point B by a rotary actuator. This mechanism permits the heads to move freely radially of the disk. The rotary actuator is suitable for reducing

25 the size of the mechanism, and therefore is employed by

all the magnetic recording systems recently made
available on the market. Also, for detecting the
radial position of the heads, servo areas are formed at
substantially regular intervals of rotation angle on

5   the disk. A detailed explanation will be given later
of the arrangement of the servo areas and the data
areas and means for detecting the radial position of
the heads based on the servo areas. A package board
has mounted thereon a hard disk controller (HDC), an

10 interface circuit, a signal processor, etc. The head
amplifier is often mounted in the enclosure in the
neighborhood of the heads in order to improve the SN
ratio and the transfer rate.

A plane view with the disk partially enlarged

15 is shown in Fig. 12. The head can be moved to an
arbitrary radial position on the disk by the rotary
actuator, but when writing or reading data, is fixed at
a specific radial position. As shown in Fig. 12,
concentric tracks are formed substantially

20 equidistantly. By way of explanation, only five tracks
are shown in solid lines. Actually, however, the
tracks, which are magnetically formed, cannot be
optically viewed directly. Although the track width is
shown in enlarged form, an actual magnetic recording

25 system has tracks in the number of several tens of
thousands formed at intervals narrower than 1 μm from
the inner to outer peripheries of the disk.

For performing the operation of following a

specific track, a technique is widely used in which a

special pattern called the servo pattern is recorded

before product shipment and a head position signal is

obtained from this pattern. This technique is

5 disclosed in JP-A-58-222468. The servo pattern is

formed in the portions designated as servo areas in

Figs. 10 and 13. Each servo area and each data area

are spaced from each other through a gap for absorbing

the variations of the rotation speed. Further, each

10 data area is divided into sector blocks of about 600

bytes including the user data of 512 bytes and

management information. The main difference between

the servo data and the data area is that the data area

is rewritten frequently in response to a user

15 instruction whereas the servo area is not rewritten

after product shipment.

About 50 to 100 servo areas are formed at

substantially equal angular intervals on the disk. The

number of the data areas is greater than that of the

20 servo areas, and therefore several data areas exist

between given two servo areas. Fig. 13 shows an

example in which a data area #1 is arranged between

servo areas #1 and #2, and the data area #1 has three

sector blocks #1 to #3 for each of four tracks #1 to

25 #4. An actual magnetic recording system has ten

thousand or more tracks, and a portion of the tracks is

shown in perpendicularly enlarged form in Fig. 13.

A pattern having a bit-direction timing

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synchronized between radially adjacent tracks is
recorded in each servo area. For forming such a
special pattern, a clock synchronized with disk
rotation is required. A servo pattern is normally

5 formed with a device called the servo track writer
having the aforementioned function. A method of
forming servo areas in this way is disclosed, for
example, in JP-A-64-48276.

A general structure of a pattern formed in

10 the servo areas and a method of producing the head
position signal called the servo information from the
servo pattern are shown in Fig. 14. In the pattern
shown in Fig. 14, an ISG (Initial Signal Gain) area is
a continuous pattern formed to reduce the effect of

15 variations in the flying height and the magnetic
characteristics of the recording film of each disk. A
servo decoder reproduces the ISG area by turning on an
automatic gain control (AGC). At the time point when a
SVAM (SerVo Address Mark) area is detected, the AGC is

20 turned off thereby to realize the function of
standardizing the reproduction amplitude of the
subsequent burst areas using the amplitude of the ISG
area. A gray code area is for describing the track
number information of each track by the gray code. The

25 sector number information may also be described in this
area. A burst area has a hound's tooth check pattern
for producing accurate radial position information and
is required for the head to follow each track

accurately. This pattern is configured of a combina-
tion of A and B bursts formed between the center lines
of adjacent servo tracks over the boundary of the
particular tracks on the one hand and a combination of

5 C and D bursts formed about the center lines of the
servo tracks on the other hand. A pad area is a
pattern formed for absorbing the delay of the servo
decoder and peripheral circuits so that the servo
decoder can maintain the clock generation during the

10 reproduction of the servo area.

The head reproduces the servo area while
running along the position curve C indicated by arrow
from left to right in Fig. 14. A part of the waveform
reproduced by this operation is shown in Fig. 15. For

15 facilitating the understanding, the reproduced
waveforms of the SVAM area, the gray code area and the
pad area are not shown. The servo decoder detects the
amplitude of the four burst areas A to D. The
reproduction signal of each burst area is converted

20 into a digital value by an A/D converter, and the
amplitude is detected by integration or Fourier
computation. The amplitude difference between the A
burst area and the B burst area makes up an N position
signal. Fig. 15 includes an equation for standardizing

25 the amplitude difference with the ISG amplitude. This
function is implemented by the servo decoder
controlling the AGC in such a manner as to secure a
constant amplitude of the ISG area. In similar

fashion, the amplitude difference between the C burst area and the D burst area constitutes a Q position signal. The head position signals produced in the manner described above are shown in Fig. 16. The N

5 position signal assumes 0 at position B where the head center covers the A burst area and the B burst area equally, and changes between positive and negative values substantially in proportion to the amount of displacement from the center position. From the

10 reproduced waveform (reproduced waveform at position C in Fig. 14) shown in Fig. 15, for example, the N position signal for position C in Fig. 16 can be obtained.

A controller for controlling the position of

15 the magnetic head produces a continuous position signal by comparing the absolute values of the N and Q position signals and connecting them by reversing the positive and negative values. In many servo patterns, a voice coil motor is controlled by setting the

20 position associated with the N position signal of 0 as a target of following. Based on the difference between the position signal and the target position, the optimum current value charged to the voice coil motor is calculated. Then, predetermined operations such as

25 the following and seek operations are performed.

The steps of forming the burst area will be explained briefly with reference to Figs. 17(a) to 17(e) and 18(f) to 18(i). The portions defined by

thick lines are patterns recorded in each step, and the width along the transverse direction of the pattern corresponds to the width of the recording track. A recording current pattern corresponding to each

5   recorded pattern is shown under the portion defined by each thick line. As shown in Figs. 14 and 15, the heads are moved at intervals of the data track, i.e. one half of the track pitch, while recording different patterns in phase. Some portions are written

10 additionally, while other portions are erased by DC field. As a result, the burst area in the shape of hound's tooth check is recorded.

Figs. 19(a) to 19(d) show the relation between a recorded magnetization pattern and a

15 reproduced wave for both the longitudinal magnetic recording system and the perpendicular magnetic recording system in comparison. The longitudinal magnetic recording system has no response to the DC magnetization, and a single-peaked output is produced

20 only at the transition. The reproduction of the recorded magnetization pattern shown in Fig. 19(a) assumes a waveform as shown in Fig. 19(b). As a result, a reproduced waveform as shown in Fig. 20(a) is obtained for the servo pattern described above, and the

25 integrated signal of absolute value of waveform for producing the position signal information assumes a form as shown in Fig. 20(b). This indicates that the amplitude of each burst and that of a corresponding

integrated signal coincide well in magnitude with each other.

However, a double-layer perpendicular recording medium having a soft magnetic under layer has 5 a response to DC magnetization, and the reproduction for the recorded magnetization shown in Fig. 19(c) assumes a reproduced waveform as shown in Fig. 19(d). Thus, the reproduction for a servo pattern similar to that for longitudinal recording assumes a waveform 10 which undesirably has a DC offset as shown in Fig. 21(a). The integrated signal of absolute value of waveform for producing the position signal information assumes a form as shown in Fig. 21(b), which fails to correctly represent the amplitude level of the burst 15 signal. The actual circuits of the reproduction system such as the AGC and the read amplifier have a characteristic of lowering the DC component. Therefore, the reproduced waveform is distorted as shown in Fig. 22, and when integrated, a correct position signal cannot 20 be produced due to the effect of the DC offset.

The burst signal portion of the burst area is arranged as described above in such a manner as to be surrounded by a large DC erased area as shown in Fig. 2. The feature of the double-layer perpendicular 25 recording is that the shorter the wavelength, the smaller the demagnetization field in the recording bits, and hence the longer the wavelength, the larger the thermal demagnetization. Fig. 23 shows an example

of the simulation result of the secular variations of
the reproduced output for the recording densities of 20
KFCI, 100 KFCI and 300 KFCI, respectively. It is seen
that the lower the recording density, i.e. the longer
5 the wavelength for bits, the larger the output
reduction. Due to a similar effect, the magnetic field
generated by magnetization of the DC erased area
described above affects the adjacent servo signal area
and promotes the thermal demagnetization of the servo
10 signal area.

In the case where the DC magnetization is
recorded as a base for recording bits, a phenomenon is
reported in which the track edge of the recorded bits
shifts along the track width according to whether the
15 particular track end coincides with the polarity of the
base DC magnetization. The end of the burst signal
area also shifts due to a similar phenomenon, thereby
deteriorating the position signal quality.

Another problem of the prior art is that the
20 maximum bit length of the signal recorded in the servo
area is longer than the maximum bit length of the data
area, and under this condition, the anti-signal decay
performance of the servo area is weakest from design
aspect, thereby making it impossible to secure
25 reliability.

SUMMARY OF THE INVENTION
An object of the present invention is to

solve the problem described above and to provide a
longitudinal magnetic recording system wherein a signal
with a shorter bit length than the burst signal, i.e. a
signal of a shorter wavelength than the burst signal is
5 recorded in what conventionally has been the DC erased
area of the servo area or an area having a very long
wavelength recorded therein. In this way, the
demagnetization field in the servo area is reduced, and
the anti-signal decay performance is improved while at
10 the same time suppressing the shift of the end of the
burst signal area for an improved servo signal quality.
In this invention, the DC erased area of the servo area
where a signal of a shorter wavelength than the burst
signal is called a dummy area.

15   Generally, the sensitivity of the reproduc-
tion head decreases for a recording signal of a shorter
wavelength. Once the wavelength of the signal recorded
in the dummy area is sufficiently shortened, therefore,
the reproduction amplitude from the signal recorded in
20 the dummy area is substantially zero and has no effect
on the detection of the position signal. In some
cases, the wavelength of the recorded signal recorded
in the dummy area cannot be shortened sufficiently due
·to the performance of the servo track writer, and the
25 reproduced output of the signal recorded in the dummy
area is sometimes large to a not negligible degree. In
such a case, the effect of the recorded signal in the
dummy area can be removed by using a LPF (Low Pass

Filter) for lowering the signal of shorter wavelength than the signal recorded in the dummy area.

The servo track writer can be controlled more easily when the signal frequency recorded in the dummy
5   area is set to an integer multiple of the signal frequency of the servo pattern. Then, the throughput of the system production can be increased for a higher cost effectiveness.

Another object of the invention is to provide
10   a magnetic recording system, wherein the maximum bit length of the servo area is limited and shortened to the maximum bit length of the data area or less. In perpendicular recording, the thermal demagnetization of the low density signal is so large that the thermal
15   fluctuation occurs most conspicuously in the portion of the recorded data on the media where the recording density is lowest. The servo pattern is indispensable data for positioning the head, and the need of preventing the disappearance thereof due to the thermal
20   fluctuation is higher than that of the user data. For this purpose, the system is designed in such a manner that the recorded bit length of the burst signal area of the servo area is set to a length at least equal to the maximum bit length of the signal recorded in the
25   disk, and under this condition, the anti-signal decay performance is secured. By designing the servo pattern in this way, the anti-signal decay performance of the servo pattern can be secured.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagram for explaining a pattern of the burst area according to this invention.

Fig. 2 is a diagram for explaining a pattern of the burst area according to the prior art.

Figs. 3(a) to 3(e) are a diagram for explaining the steps of forming a pattern of the burst area according to the invention.

Figs. 4(f) to 4(i) are a diagram for explaining the steps of forming a pattern of the burst area according to the invention.

Fig. 5 is a diagram for explaining a configuration of the servo system according to a first embodiment of the invention.

Fig. 6 is a diagram for explaining the reproduced waveform of the servo area in the case where a data LPF is used according to a first embodiment of the invention.

Fig. 7 is a diagram is a diagram for explaining the reproduced waveform of the servo area according to the first embodiment of the invention.

Fig. 8 is a diagram for explaining a configuration of the servo system according to a second embodiment of the invention.

Fig. 9 is a diagram for explaining the system configuration according to a third embodiment of the invention.

Fig. 10 is a plane view showing an example of

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the structure of an ordinary magnetic recording system.

Fig. 11 is a sectional view showing an example of the structure of an ordinary magnetic recording system.

5   Fig. 12 is an enlarged view showing an example of the structure of an ordinary magnetic recording system.

Fig. 13 is a diagram for explaining an example of the structure of the tracks of an ordinary

10   magnetic recording system.

Fig. 14 is a diagram for explaining a servo pattern of an ordinary magnetic recording system.

Fig. 15 is a diagram for explaining a reproduced waveform of the servo pattern of an ordinary

15   magnetic recording system.

Fig. 16 is a diagram for explaining the position signal of an ordinary magnetic recording system.

Figs. 17(a) to 17(e) are a diagram for

20   explaining the steps of forming a servo pattern of an ordinary magnetic recording system.

Figs. 18(f) to 18(i) are a diagram for explaining the steps of forming a servo pattern of an ordinary magnetic recording system.

25   Figs. 19(a) to 19(d) are a diagram for explaining the difference of reproduction between longitudinal recording and perpendicular recording.

Figs. 20(a) and 20(b) are a diagram for

explaining a reproduced waveform in an application of
the servo pattern of the conventional magnetic
recording system to longitudinal recording.

Figs. 21(a) and 21(b) are a diagram for
5 explaining a reproduced waveform in an application of
the servo pattern of the conventional magnetic
recording system to perpendicular recording.

Fig. 22 is a diagram for explaining a
reproduced waveform in an application of the servo
10 pattern of the conventional magnetic recording system
to the perpendicular recording with a reproduction
system having a low-pass filter.

Fig. 23 is a diagram for explaining the
thermal demagnetization characteristic of perpendicular
15 magnetic recording.

DESCRIPTION OF THE EMBODIMENTS
(First embodiment)

A first embodiment will be explained.
According to this embodiment, there is provided a
20 longitudinal magnetic recording system in which a
pattern having a recording density twice as high as the
burst signal, i.e. having a bit length one half that of
the burst signal is recorded in an area which has
conventionally been a DC erased area (area II in Fig.
25 2), i.e. a dummy area, as shown in Fig. 1.

The steps of forming the burst area with a
servo writer will be explained with reference to Figs.

3(a) to 3(e) and 4(f) to 4(i). As in the conventional longitudinal recording system, a burst pattern is formed at pitches of one half track. In what has conventionally been the DC erased area, however, a
5 pattern having bits one half of the burst signal area is recorded. As a result, a burst pattern of hound's tooth check is formed on both sides of the dummy signal area.

Fig. 5 shows an outline of the servo system
10 configuration. The longitudinal magnetic recording system also often comprises a LPF for lowering the high-frequency noise in the stage following the read amplifier. In many cases, however, a servo LPF is also used as a data LPF at the same time. According to this
15 embodiment, an LPF for lowering the signal from the dummy area is used to reduce the cut-off frequency of the LPF as compared with that of the LPF used for reproducing the recorded signal in the user data area. A selector is arranged in the stage before the LPF and
20 the switching operation of the selector is controlled by a HDC (Hard Disk Controller).

The recording density of the burst signal area is considerably lower than the maximum recording density of the data area. In other words, the
25 frequency of the recorded signal in the burst signal area is considerably lower than that in the data area. According to this embodiment, the frequency of the dummy signal area is twice as high as the frequency of

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the burst signal area. A frequency twice as high,
however, cannot still permit the reproduced signal from
the dummy signal area to be ignored. In the case where
a LPF set in the same manner as in the data area is

5   used for the servo area, therefore, a signal is
undesirably produced even in an area where the signal
should otherwise be zero as shown in Fig. 6, thereby
deteriorating the quality of the position signal. In
view of this, a LPF having such a cut-off frequency is

10 provided as to sufficiently pass the burst signal
frequency while cutting off the signal of the dummy
signal area. In this way, the amplitude of the dummy
signal area can be reduced substantially to zero. In
this embodiment, the frequency of the dummy area is

15 twice as high as that of the burst signal area.
Therefore, the cut-off frequency of the LPF for the
servo area is set to 1.5 times as high as the frequency
of the burst signal. As a result, the reproduced
signal in the burst area, as shown in Fig. 7, assumes a

20 waveform substantially similar to that of the
integrated waveform of the absolute value for
longitudinal recording. Thus, the conventional servo
control method can be used as it is.

        The present embodiment uses a system having

25 two LPFs which are switched appropriately.
Alternatively, it is of course possible to use a single
LPF having a variable cut-off frequency which is
switched as required.

(Second embodiment)

A second embodiment will be explained. According to this embodiment, the steps of forming the burst area are exactly the same as those of the first

5 embodiment, but the servo signal processing system is different. Fig. 8 shows an outline of the processing system. Unlike the first embodiment in which the amplitude is calculated by integrating the absolute value, the present embodiment is such that the

10 frequency component is detected (phase is detected) by use of DFT (Discrete Fourier Transform) thereby to control the position signal. The phase is detected by the frequency but not by the amplitude of the servo signal and that the frequency of the dummy area is

15 different from that of the burst signal area. Therefore, the frequencies of the dummy area and the burst signal area can be discriminated readily. Thus, the LPF for the servo area is eliminated, and a LPF similar to that for the data area can be used.

20 (Third embodiment)

A third embodiment will be explained. According to this embodiment, the steps of forming the burst area and the servo signal processing system are exactly the same as those of the second embodiment. In

25 this embodiment, however, the recording density of the burst signal area is subjected to certain conditions. As described above, the thermal demagnetization of the low-density signal is large in perpendicular recording.

That portion of the recorded data on the media which
has the lowest recording density, therefore, most
easily succumbs to the thermal fluctuation. According
to this embodiment, the burst signal is recorded with a
5   bit length shorter than the maximum bit length limited
by the recorded code in the data area.

This embodiment uses a code having the
efficiency of 32/33 in which 33 recorded bits are
assigned to 32 user data bits as a recorded code. With
10 this code, the longest recorded bits are ten times as
long as the shortest recorded bits. The magnetic
recording system according to this embodiment is
divided into radial zones as shown in Fig. 9, and data
are recorded in each zone with a fixed transfer rate.
15 The linear recording density at each radial position is
determined by the relation between each radial position
and transfer rate. According to this embodiment, the
recording density is lowest for the outermost
peripheral zone, of which the maximum bit length is
20 equal to that of the data area of the system. The
recording density of the burst signal area of the servo
area, therefore, is required to be set to a length
equal to or shorter than the maximum bit length.
According to this embodiment, the recording density of
25 the burst signal area is set to the same bit length as
the maximum bit length. Therefore, the bit length of
the dummy signal area is set to twice as long.

As a result, the maximum bit length in the

system coincides with the maximum bit length of the
data area. As long as the anti-signal decay
performance is secured under this condition, therefore,
the anti-signal decay performance of the servo signal

5   can be secured. In this way, the reliability of the
system is secured.

The first to third embodiments described
above use perpendicular magnetic recording media having
a soft magnetic backing layer. Even in the case where

10 a single-layer perpendicular magnetic recording medium
lacking a soft magnetic backing layer is used, however,
the same concept applies to thermal demagnetization.
Thus, the lower the density of a recorded signal, the
larger the thermal demagnetization. Also, the

15 processing in the servo area, though different in
reproduced waveform, can be performed in exactly the
same way. Thus, the present invention is effectively
applicable even to the perpendicular magnetic recording
media having no soft magnetic backing layer.

20   It will thus be understood from the foregoing
description that according to this invention, there is
provided a magnetic recording system using
perpendicular magnetic recording media, wherein a servo
control method similar to that for the longitudinal

25 recording can be used for a reduced development cost.
Also, the fact that the long wavelength signal which
easily succumbs to thermal demagnetization is not used
can achieve a thermal stability. Further, by

suppressing the variations of the burst signal along

the track width, the positioning operation can be

performed using a highly accurate position signal.

Thus, a highly reliable magnetic recording system of

5 large capacity can be provided.